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US Army Research Laboratory

A Low Velocity 0.30-cal. Gun System

by Donald J Little
Weapons and Materials Research Directorate

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14. ABSTRACT

An efficient method was needed to perform ballistic testing using 0.30-cal. Fragment Simulating Projectiles at or near subsonic velocity in order to screen new resin systems for advanced composite/ceramic armor scaled-down test coupons. This technical note outlines the custom gun system and testing methods developed to enable this ballistic testing.

15. SUBJECT TERMS

0.30-cal., low velocity, gun systems, fragment simulator projectiles, ballistic testing

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Contents

List of Figures

List of Tables

1. Introduction

Rapid screening of new resin systems for advanced composite/ceramic armor dictated conducting ballistic experiments on scaled-down test coupons. These S-2 glass/epoxy panels had a nominal areal density of 2 psf (9.75 kg/m^2). These material systems were intended for service as back plates in ceramic composite armor systems and, because they were optimized as structural elements, their ballistic performance is rather low. The panel V_{50} testing was conducted according to Department of Defense standard MIL-STD-662F.[1] By characterizing V_{50} and the resulting delaminating damage near the ballistic limit for targets at a 2-psf (9.75-kg/m^2) areal density, a large number of resin candidates could be evaluated in a very short amount of time. Fragment Simulating Projectiles (FSPs) are useful for this type of screening because when employed at a low enough velocity no deformation (mushrooming) of the projectile occurs. The 0.30-cal. FSP,[2] shown in Fig. 1, is an appropriate test projectile for the targets of this type.

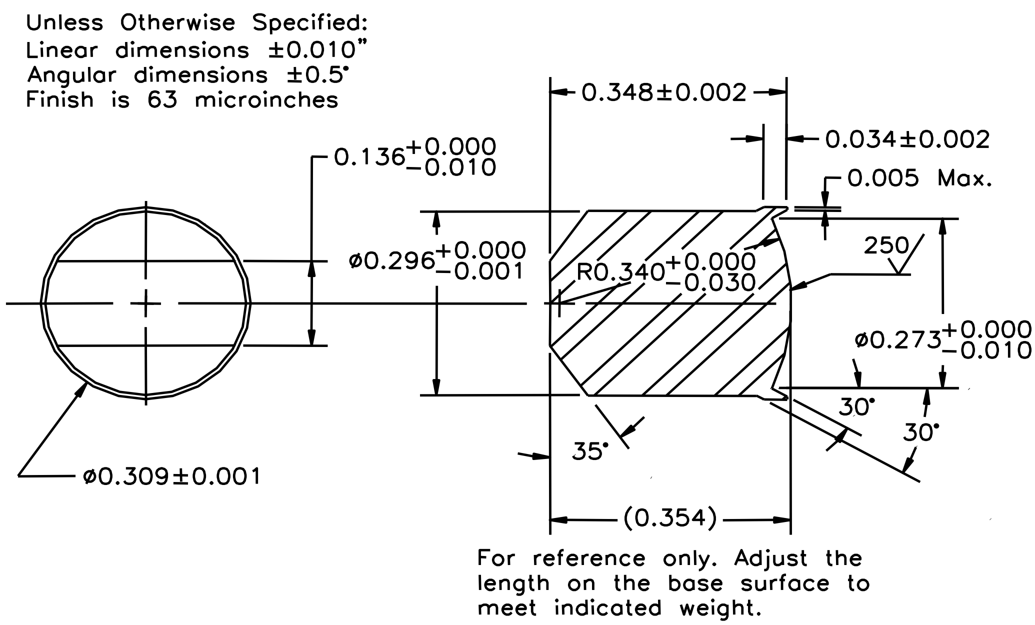

Fig. 1 0.30-cal. FSP

V_{50} testing for these evaluations required projectile impact velocities near the speed of sound in air. It is exceedingly difficult to get precise velocity control of gun-fired FSPs in this velocity regime using a conventional powder gun. This necessitated the development of a 0.30-cal. gun system tailored specifically to this velocity regime and projectile weight. Standard testing barrel lengths (18–30 inches) and standard commercial reloading propellants have shown they are not very efficient when testing at extremely low velocities with very light projectiles. One factor that inhibits velocity consistency when ballistic firing FSPs is pressure buildup between the seated fragment and cartridge case tends to deform and collapse the case wall. This is due to the fragment being seated in the barrel bore separate from the cartridge case, which leaves a gap between the top of the cartridge case and seated fragment. This gap allows a space where chamber pressure can escape along the outside of the case and results in inconsistent chamber pressures, which in turn cause velocity control and velocity repeatability issues. This problem is more pronounced at higher pressures but is observed over all velocity ranges. By contrast, a standard cartridge has the projectile seated inside the neck of the case, and the pressure during propellant ignition presses the case against the chamber, thereby creating a pressure seal. Figure 2 shows deformation and carbon trails caused by chamber gas leaking around the cartridge case during an FSP shot. Figure 3 is a cross section of a test barrel loaded with a 0.30-cal FSP to illustrate the problem area.

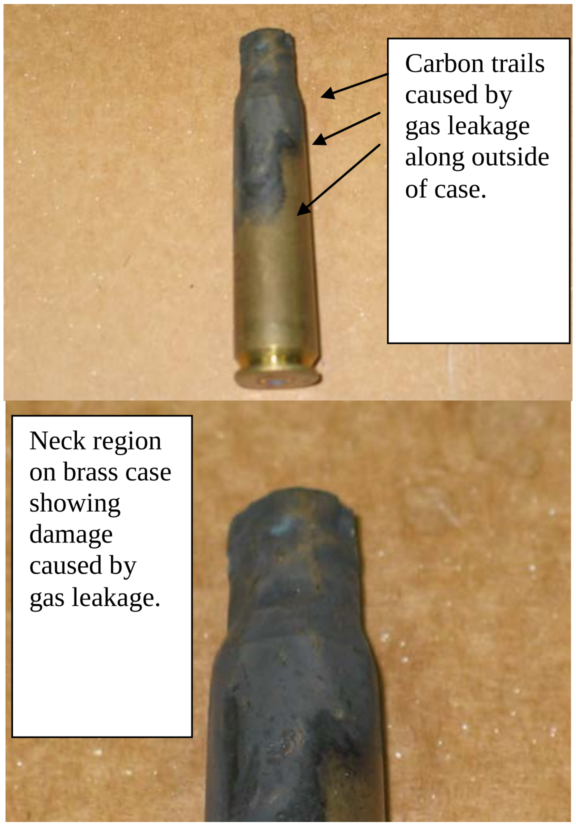

Fig. 2   Standard brass case used to launch FSPs

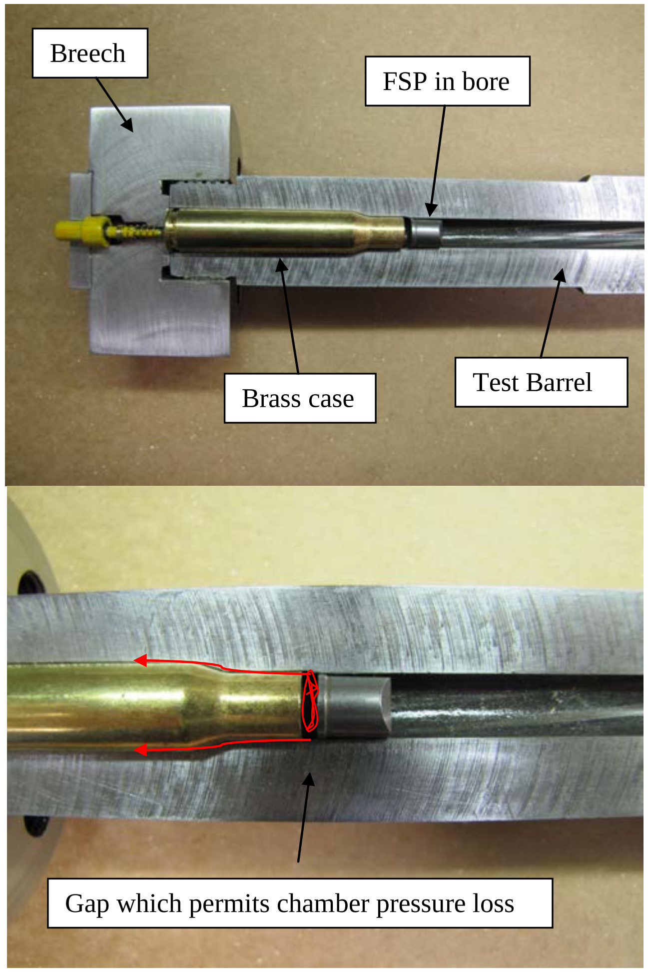

Fig. 3   0.30-cal. FSP seated in test barrel

2. Approach

Past experience from FSP testing has shown the best approach to achieve very low velocities is to use a short barrel and a very fast burning propellant.[3] For these experiments, a barrel was made by cutting a 267-mm (10.5-inch)-long segment from a standard length 0.30-cal. testing barrel. The barrel has 3 lands and 3 grooves and a twist rate of one turn for every 10 inches of length. The chamber of the barrel was reamed to accept a .30–06 Springfield case and threaded to accept the screw-on small-caliber percussion pin lab breech. Figure 4 shows the barrel and the barrel mounted in the test fixture that was used for testing.

Fig. 4 Testing barrel and barrel fixed in mount

To mitigate case deformation and improve chamber pressure consistency, a thick rigid-wall custom cartridge case with a reduced internal volume was constructed from 17-4 PH stainless steel. The external geometry of the case was dimensioned to match a standard .30-06 case. The internal cavity was made by plunging a 5.95-mm (15/64-inch)-diameter standard twist drill bit to the same depth as the inside of a standard .30-06 brass case. The thick body provides stiffness and rigidity and resists deforming and collapsing inward as pressure builds between the seated fragment and the cartridge case. Figure 5 shows a custom case made for these tests alongside a standard .30-06 brass case.

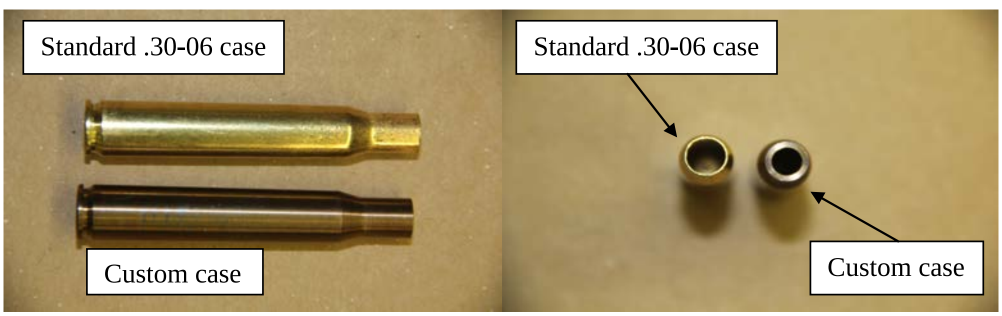

Fig. 5 Custom cases and standard .30-06 cases

The custom cases were heat treated to give them a temper that would yield durability and strength to allow repeated use. The cases were heated to 900 °F and held for 1 h, then air cooled to ambient temperature. This process on 17-4 PH stainless steel increases the tensile strength and produces a hardness of 40-42 Rockwell C scale.

The thick rigid-wall design of the custom case reduces chamber pressure loss but does not eliminate it entirely. An additional step performed while using the custom cases for these tests added a small band of masking tape around neck prior to loading it into the barrel. When the weapon was fired, the tape was forced

down to the neck transition area of the case and formed a simple seal that helped contain pressures within the chamber area. The tape was approximately 5.08 mm (0.200 inch) wide and long enough to go around the case neck one time. Testing performed with and without the tape showed a definite improvement with velocity control when tape was used. The tape appears to provide the most benefit at lower velocities and appears to fail with larger propellant loads and higher pressures. Figure 6 shows a custom case pre- and posttest with tape in place.

Fig. 6 Tape band fixed around end of custom case

FSPs are individually machined parts where a certain amount of variation from part to part is normal. To improve consistency, prior to using them for these tests, the FSPs were all passed through a steel resizing die to achieve a more consistent and uniform flare diameter, thus reducing variation of fit within the bore of the gun. The die is a commercially available swaging die with an internal diameter of 7.848 mm (0.309 inch). Each FSP was gently tapped through the die using a copper rod punch and small hammer. Figure 7 shows the die and tools used to perform the resizing step.

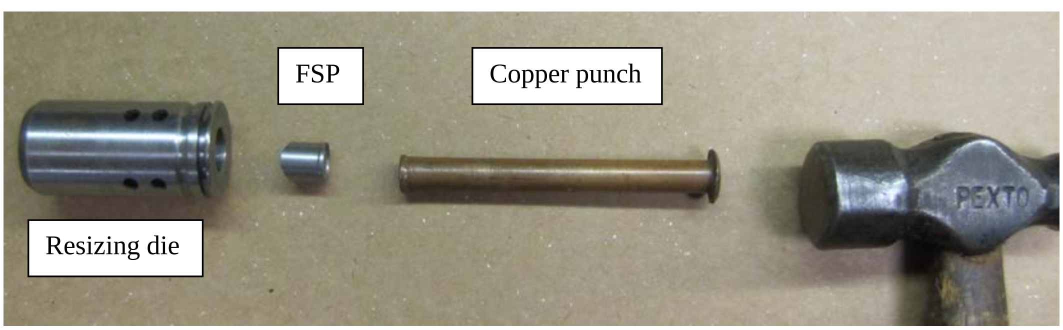

Fig. 7 Resizing die with fragment and accompanying tools

Variation in FSP weight also contributes to velocity variations during testing. For these tests the FSPs were sorted by weight into groups of 10 that where within ± 0.3 gr of one another. A group was then set aside for each panel to be evaluated.

Another factor that will affect velocity is varying the FSP seating depth in the test barrel. FSPs must be seated in the gun at precisely the same depth for each test to achieve consistent velocities. A custom seating tool was made from a piece of all-thread to perform this step. Two locking nuts and a stop washer were added to set the stopping point on the back of the barrel. This seating tool was then adjusted to seat the fragment 1.58 mm (1/16 inch) into the rifling of the gun. Figure 8 shows the tools used to perform this step.

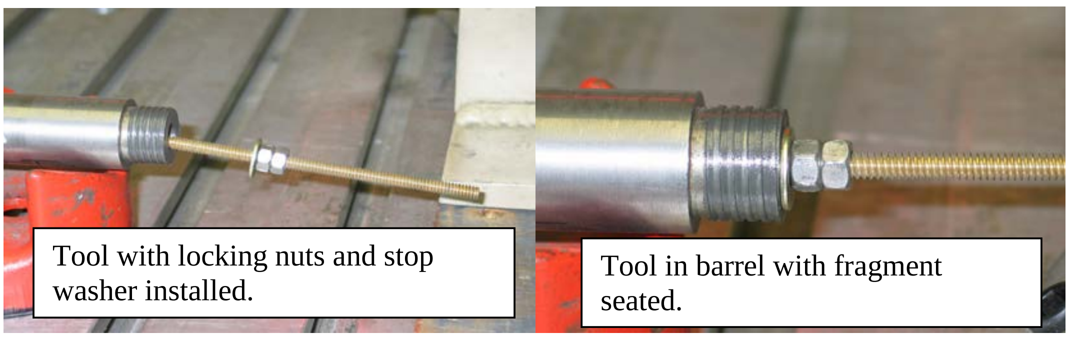

Fig. 8 Seating tool used to precisely seat FSP projectile in gun barrel

The propellant used for these experiments was Bullseye smokeless pistol powder, a very fast burning propellant manufactured by Alliant. The primer used was Federal Gold Match large rifle percussion primers manufactured by Federal Ammunition.

Keeping the propellant charge evenly seated in the base of the case against the primer is also important factor in velocity consistency. A small piece of tissue of approximately 19.05 mm (0.750 inch) diameter was pushed down inside the case on top of the propellant charge using a small wooden dowel (Fig. 9).

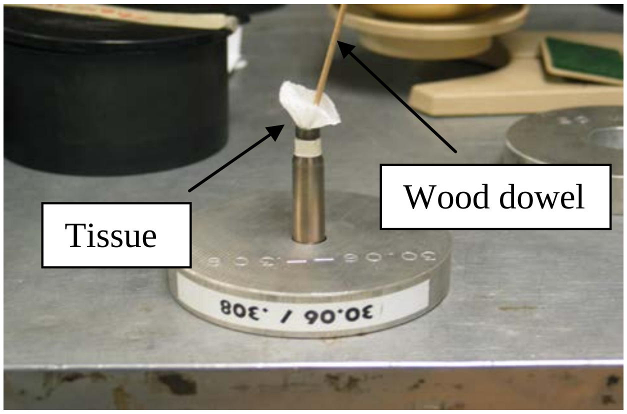

Fig. 9 Tissue seating

3. Experiments

The layout of the ballistic range for these experiments is shown in Fig. 10.

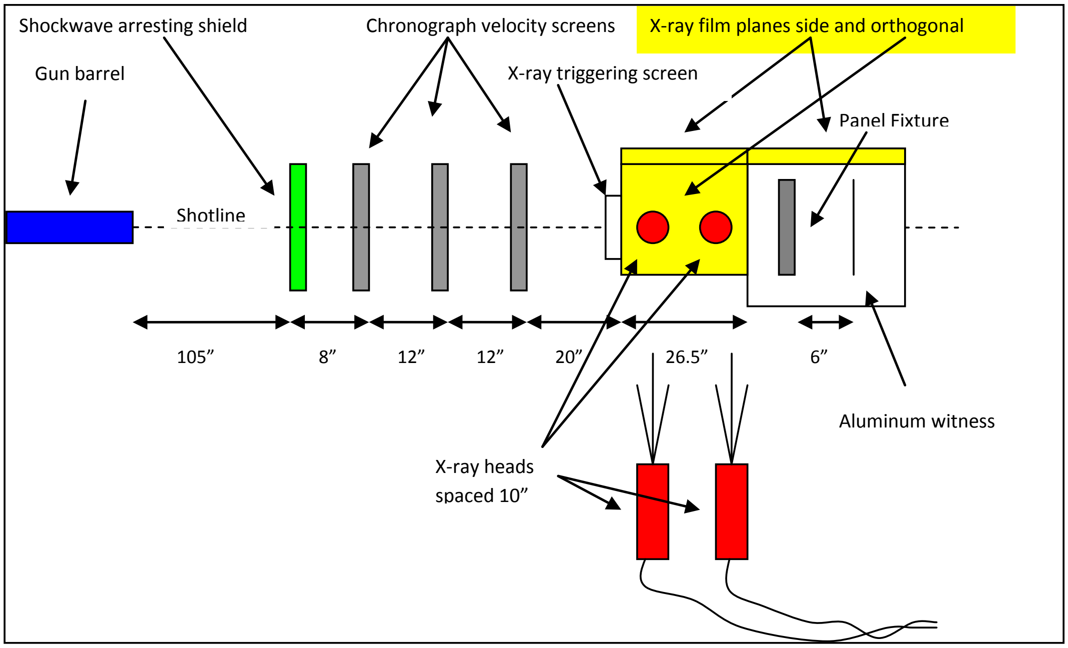

Fig. 10 Ballistic range layout and parameters

An Oehler chronograph system with 3 model 57 infrared screens spaced 304.8 mm (12 inches) apart was used to collect and record velocity data for these tests. A few test shots were performed initially using 2 channels of orthogonal flash X-rays to measure fragment yaw characteristics in flight to confirm it was within acceptable levels (<5 degrees total). Since the test shots yielded yaw measurements well within the requirement, the bulk of testing was completed using chronographs only to capture velocity data.

For this testing it was necessary to install a shock wave arresting shield directly in front of the first chronograph screen to get consistent triggering of the chronograph system. Since the velocity regime was subsonic (below the speed of sound in air), the shock wave traveled ahead of the projectile and caused false triggering of the chronograph screens. The shield was made from a piece of plywood with a 25.4-mm (1.0-inch) hole drilled in it. A piece of masking tape was placed over the hole for each shot to block the shock wave but allow the FSP to easily pass through. Figure 11 shows the shield in place forward of the testing barrel and in front of the chronograph screens.

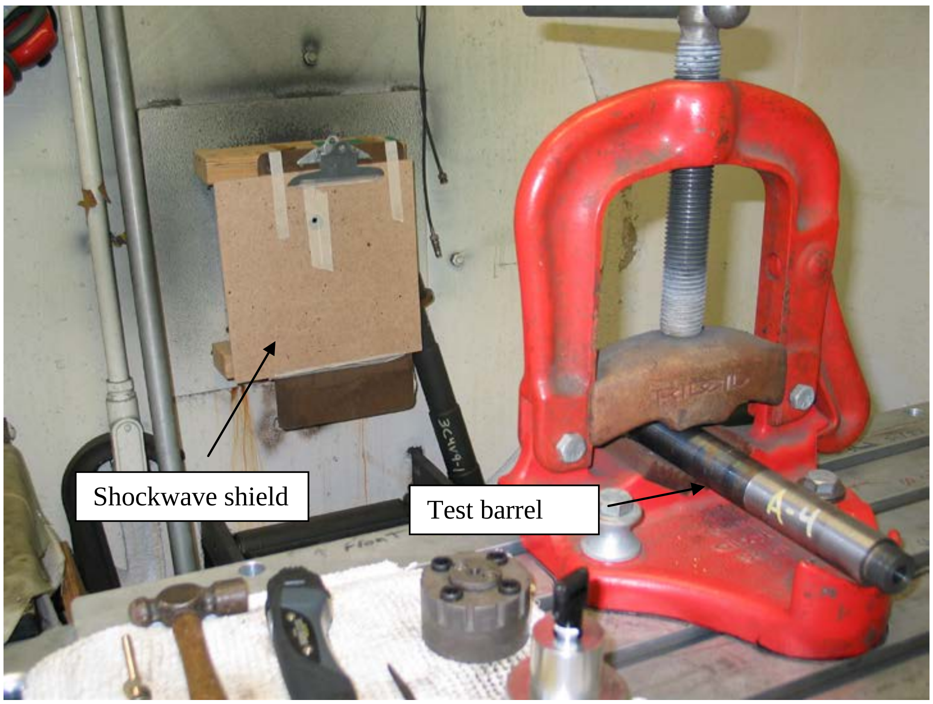

Fig. 11 Subsonic shock wave shield mounted forward of testing barrel

Prior to starting panel evaluations, ballistic firing was completed to create a propellant reloading curve and create data to evaluate both velocity consistency and control. These data are shown in Fig. 12. For comparison, Fig. 13 contains 0.30-cal. FSP testing data using standard 0.30-cal. reloading propellant with brass cartridge cases and an 889-mm (35-inch)-long test barrel.

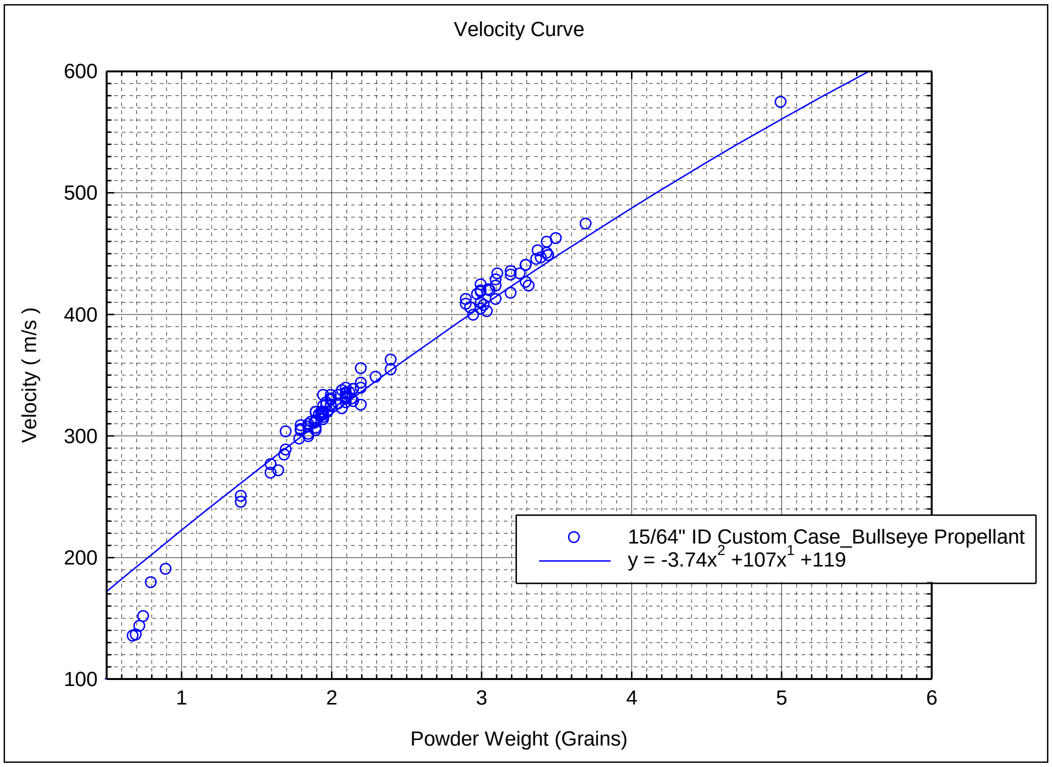

Fig. 12 0.30-cal. FSP launch velocity as a function of propellant load for custom case and 10.5-inch-long test barrel

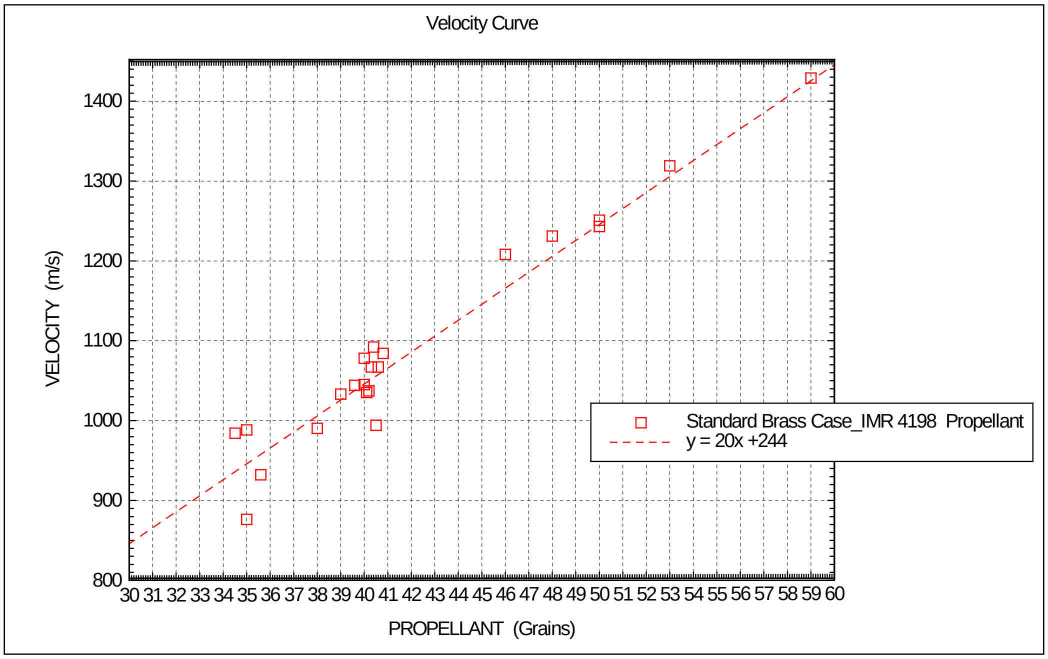

Fig. 13 0.30-cal. FSP launch velocity using standard components

The V_{50} evaluation on the panels required ballistic firing to continue until 3 partial penetrations (PPs) and 3 complete penetrations (CPs) within a 90 ft/s spread were obtained. The V_{50} is defined as the impact velocity at which the projectile has a 50% probability of perforating (defeating) the target. A 0.51-mm (0.020-inch) 2024-T3 aluminum witness plate was positioned 152 mm (6 inches) behind the target to determine the outcome of each shot. An impact is regarded as a CP, or loss, if the projectile or a resulting target fragment from impact creates a hole in the witness plate through which light can be observed. If an impact does not result in a CP, it is considered a PP or win. The Table contains V_{50} data collected using the custom case, barrel, and test methods outlined previously.

Table V_{50} test data

AMB Shot No.	Propellant Weight (gr)	Velocity (ft/s)	Result	FSP Weight (gr)	Data Summary
9311	2	1087	PP	43.79	Panel 1
9312	2.4	1179	CP	43.67	
9313	2.2	1137	PP	43.89	
9314	2.3	1151	CP	43.88	Used for V_{50} calculation
9315	2.25	1133	PP	43.65	V_{50} ft/s = 1146
9316	2.3	1144	CP	43.82	Standard Deviation ft/s = 18
9317	2.25	1133	PP	43.74	
9329	2.1	1090	CP	43.59	Panel 2
9330	1.9	1016	PP	43.78	
9331	2	1069	PP	43.86	
9332	2.05	1071	PP	43.83	Used for V50 calculation
9333	2.2	1087	CP	43.99	V50 ft/s = 1081
9334	2.1	1109	CP	43.77	Standard Deviation ft/s = 19
9335	2	1057	PP	43.73	
9348	2.3	1147	PP	43.72	Panel 3
9349	2.5	1222	CP	43.75	
9350	2.4	1170	CP	43.66	Used for V_{50} calculation
9351	2.3	1143	PP	43.81	V_{50} ft/s = 1177
9352	2.4	1180	PP	43.87	Standard Deviation ft/s = 31
9353	2.5	1202	CP	43.57	
9354	2.5	1179	PP	43.71	Panel 4
9355	2.6	1228	CP	43.66	
9356	2.55	1203	PP	43.72	
9357	2.6	1248	CP	43.67	Used for V_{50} calculation
9358	2.55	1186	CP	43.64	V_{50} ft/s = 1190
9359	2.46	1181	CP	43.58	Standard Deviation ft/s = 22
9360	2.4	1164	PP	43.61	
9374	2.2	1123	CP	43.88	Panel 5
9375	1.9	1028	PP	43.75	
9376	2.05	1057	CP	43.78	
9377	1.98	1060	CP	43.77	
9378	1.85	930	PP	43.71	Used for V_{50} calculation
9379	1.9	1017	PP	43.51	V_{50} ft/s = 1035
9380	1.95	1041	CP	43.53	Standard Deviation ft/s = 21
9381	1.89	1007	PP	43.8	
9382	2	1054	PP	43.65	Panel 6
9383	2.2	1107	PP	43.63	
9384	2.5	1164	PP	43.66	
9385	2.67	1238	CP	43.78	
9386	2.59	1187	CP	43.78	Used for V50 calculation
9387	2.57	1181	PP	43.7	V50 ft/s = 1199
9388	2.58	1238	CP	43.65	Standard Deviation ft/s = 31
9389	2.48	1185	PP	43.88	
9407	1.86	966	PP	43.91	Panel 7
9408	1.96	1016	CP	43.61	
9409	1.91	1010	CP	43.61	Used for V_{50} calculation
9410	1.8	946	PP	43.68	V_{50} ft/s = 991
9411	1.85	981	PP	43.64	Standard Deviation ft/s = 31
9412	1.98	1026	CP	43.66	
9413	1.9	980	PP	43.78	Panel 8
9414	1.97	1078	CP	43.98	
9415	1.89	1024	CP	43.87	
9416	1.8	982	PP	43.86	Used for V_{50} calculation
9417	1.85	1021	CP	44	V_{50} ft/s = 1002
9418	1.82	1027	CP	43.93	Standard Deviation ft/s = 24
9419	1.75	980	PP	44.09	
9436	2.1	1114	PP	44.01	Panel 9
9437	2.2	1130	CP	44.05	
9438	2.15	1113	CP	44.14	Used for V_{50} calculation
9439	2	1046	PP	44.85	V_{50} ft/s = 1099
9440	2.07	1106	CP	43.84	Standard Deviation ft/s = 30
9441	1.95	1086	PP	43.68	
10650	2	1063	CP	43.7	Panel 10
10651	1.8	1011	PP	43.7	
10652	1.9	1048	CP	43.5	
10653	1.8	1001	PP	43.9	Used for V_{50} calculation
10654	1.85	1007	PP	43.5	V_{50} ft/s = 1025
10655	1.95	1093	CP	43.7	Standard Deviation ft/s = 25
10656	1.9	1022	CP	43.7	
10659	1.79	975	CP	44.02	Panel 11
10660	1.4	820	PP	43.92	
10661	1.6	883	PP	44.02	
10662	1.7	946	CP	44.09	Used for V_{50} calculation
10663	1.65	887	PP	44.02	V_{50} ft/s = 917
10664	1.69	932	CP	43.91	Standard Deviation ft/s = 27
10665	1.6	904	PP	44.04	
10666	1.4	803	CP	43.96	Panel 12
10667	0.9	622	CP	43.9	
10668	0.5	313	PP	44.17	
10669	0.7	446	PP	43.96	
10670	0.8	587	CP	44	Used for V_{50} calculation
10671	0.75	497	CP	44	V_{50} ft/s = 463
10672	0.725	468	CP	44	Standard Deviation ft/s = 25
10673	0.68	442	PP	43.96	

Note: Highlighted lines represent those used forV_{50} calculations.

4. Conclusion

Comparing velocity curves for the custom barrel and case to data using standard components (Figs. 12 and 13), the custom barrel and case produce increased velocity consistency for a given propellant load.

Each panel required a minimum of 6 tests to establish the V_{50} limit. At most, only 3 additional tests over and above the 6-shot minimum requirement were needed to complete each panel. The reduced number of tests required to complete each panel further showcase the efficiency and control of this gun and custom case combination when testing in this velocity regime. The reduced testing expedited the evaluation of this initial batch of composite panels.

When a powder gun is used to test in this low-velocity regime, it requires consistency and attention to detail during the loading and firing process. Over 500 tests using this system and testing method have been conducted in support of US Army Research Laboratory and customer programs to date.

5. References

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